Long-Run Changes in Driver Behavior Due to Variable Tolls

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ABSTRACT

Managing congestion on highways, especially in urban areas, has been a major challenge for transportation planners and researchers. Variable pricing, specifically time-of-day congestion pricing, is one possible method to manage demand and reduce congestion. As many variable pricing projects are still in the implementation stage, long-run driver responses to the variable tolls are largely unknown. This paper examines the long-run changes in driver behavior in an existing variable pricing project in Lee County, Florida. Using empirical evidence, it was found that over time the relative price elasticity of demand on the Midpoint Memorial Bridge has decreased from –0.42 to –0.11 during the early morning discount period. The elasticities have decreased, but to a lesser extent during the late morning and early afternoon discount periods. A discount period volume spreading ratio was developed and the elasticity results were confirmed using this method of analysis.

It was also found that certain characteristics such as frequency of trips, commute trip purpose, full-time employment status, number of people in the household, higher education, and age between 25–34 years were all indicators that the participant may increase his or her variable pricing usage over time. Other characteristics, including being retired and having a household income less than $16,000, were indicators that the driver may not increase their variable pricing participation. These results may not be typical for variable pricing facilities. Additional factors, such as the characteristics and influence of any alternate routes, traveler demographics, and the size of the toll discount need to be considered for each project. However, the methodology developed in this research can be applied to other projects in order to determine those price elasticities of demand and their change over time.

Key Words: Variable Tolls, Elasticity, Long-run, Behavioral Changes, Peak Spreading

INTRODUCTION

Understanding and measuring price elasticities of demand has begun to play a more important role in transportation with the implementation of congestion pricing as a means to manage the ever-increasing demand for transportation infrastructure and services. To evaluate the impacts of transportation pricing strategies, it is necessary to understand drivers' response to changes in price. Price elasticity of demand is an empirical measure that summarizes demand for a given highway facility at a given point of time in a single number (*1*). It is defined as the percentage change in quantity demanded divided by the percentage change in price. Price elasticities of demand are necessary for cost/benefit analyses and are helpful to study motorist behavior .

Variable pricing generally involves a toll that varies by the amount of traffic on the highway, with higher tolls during the peak period and lower tolls during the off-peak period. This variable toll can be set based on the time of day, targeting the traditional peak hours based on a fixed daily and weekly schedule, or it can be set based on the level of congestion that exists on a particular network at a particular point of time. Recent technological advances have made both forms of variable tolling practical and cost efficient for implementation.

To determine the appropriate size of the variable toll, which may vary by either time of day or level of congestion, information is required on drivers' willingness to pay and their responsiveness to price changes (*1,2,3,4,5*). A reduction of 10 percent of peak period traffic may increase the peak period travel speeds by much more than 10 percent due to traffic flow characteristics when the volumes approach the capacity of a roadway (*2*). Although an extensive amount of research has been done to determine driver price elasticities of demand, limited research has been done to determine the price elasticities of demand with respect to variable tolls and how they change over time.

The first objective of this research was to calculate and compare price elasticities of demand over time in an existing variable pricing project. The second objective was to construct a model similar to the peak spreading model to validate the elasticity results. The third objective was to identify socio-economic and commute characteristics which may have impacted drivers' changes in travel behavior over time.

BACKGROUND

Toll Price Elasticities of Travel Demand

The available literature on toll price elasticities of travel demand deals primarily with elasticities based on a fixed toll, which does not vary by time of day or congestion level. Based on a review of nine studies, Burris (2003) found that the fixed-toll price elasticity of travel demand varies from –0.03 to –0.35 (*5*). Given the lack of experience with variable pricing on toll roads, there is limited empirical data available on variable-toll price elasticity of travel demand. Burris (2003) reviewed four studies that estimate variable-toll price elasticities and found that they vary from –0.16 to –1.0 (*5*). He also found that the absolute value of price demand elasticities were greater for tolls that vary by time of day or traffic level, as drivers have an added incentive to explore more options in scheduling their time of travel.

In the long run, drivers have more opportunities to change their travel behavior in response to a change in price. Hence, long-run elasticities tend to be higher than short-run elasticities. Economists consider the long-run period as the time in which a driver can change all of his/her input travel variables and the short run as time period in which he/she can't change all of his/her travel input variables (*6,7,8*). However, in the reviewed literature, the period defined as long run was often left to the individual author's discretion. In general, short-run elasticities were considered within 1 year of price changes and long-run elasticities were considered within a span of 3 to 5 years (*1,9,10*). Almost all the available estimates in the reviewed literature suggest that the long-run elasticities are at least twice those of corresponding short-run elasticities (*1,3,11,12*). The change in price elasticities of demand over time is not only due to travelers adjusting their travel input variables but also may be due to the change in driver response without any other changes (*13,14,15*).

DATA COLLECTION AND DESCRIPTION

Lee County Variable Pricing Project

The data used in this research were obtained as a part of the Lee County variable pricing project, which is one of the few operational projects under the Federal Highway Administration's value pricing pilot program. Implemented in August 1998, it is a mature pricing program and, based on previous discussion, is beyond the time frame within which short-term elasticities are in effect and is well into the time frame for long-term elasticity effects to have manifested. Therefore, data used in this research are based on the real-world response of drivers to variable tolls over a long-term time period.

In an effort to both manage traffic congestion and better understand driver responses to variable tolls, variable pricing, a form of value pricing, was introduced on August 3, 1998, on two heavily traveled toll bridges in Lee County, Florida. The current variable pricing program entitles Cape Coral and Midpoint Memorial Bridge users to receive a 50 percent discount on their toll during the discount periods. These discount periods (6:30–7:00 a.m., 9:00–11:00 a.m., 2:00–4:00 p.m., and 6:30–7:00 p.m.) were chosen as the most likely to entice drivers traveling during the peak period to change their time of travel to the shoulder periods.

Drivers on these toll bridges effectively have three methods of payment available to them. Drivers without a transponder and a PrePay account (termed as *ineligible drivers)* must pay cash (one dollar toll). However, drivers with transponder and without a PrePay account (were also *ineligible drivers*) by enrolling in a frequent user discount program (for a fee $40.00 per year) were eligible for 50 percent of their normal toll charge. Only those drivers who have both transponder and PrePay account (termed as *eligible drivers*) were eligible for variable pricing toll discounts. By driving during the discount periods, eligible drivers who were initially paying $1.00 could pay only $0.50 and drivers who were initially paying $0.50 could pay only $0.25. The majority (94 percent) of drivers eligible for the toll discount were in the latter category, saving $0.25 per trip.

The Lee County variable pricing project is a unique project, as the congestion on the toll bridges was not excessive (the level of service in the peak period was 'C'). Therefore, driver participation in this variable pricing program primarily depended on the economic incentive of toll discounts and not on the travel time savings obtained by driving during the discount periods. The toll discounts in the Lee County project were not sufficient to cause a significant change in the mode of travel, location of housing, or location of employment (*5,16*). Hence, the change in driver participation in the variable pricing program over time can be primarily attributed to the changes in driver perception toward the toll discounts.

To help judge the success of this variable pricing project, driver response to the variable toll was continuously monitored. Early results on how variable pricing impacted traffic patterns on Lee County toll bridges has been documented in several papers (*5,16,17,18*). Therefore, this paper will focus on long-term impacts of variable tolls on driver behavior. To examine the long-term impacts, traffic volume data on Lee County toll bridges and socio-economic and commute characteristics of drivers who have changed/not changed their frequency of variable pricing program participation were collected.

Traffic Volume Data Description

Data on traffic flow by payment type from 1998 to 2002 were obtained from both variably priced bridges. As each vehicle passed through the toll plaza, toll plaza equipment recorded the time of transaction and the method of toll payment. In this research, every vehicle that crossed the Cape Coral and Midpoint Memorial Bridges was accounted for and included in the analysis. Therefore, while comparing traffic patterns statistical tests were not shown, as the entire population was included in the analysis.

Initial preparation of raw data files required extensive use of Excel® spreadsheets. From the collected data, weekends and public holidays (New Years Day, Memorial Day, Independence Day, Labor Day, Thanksgiving, and Christmas) were excluded, as toll discounts were not offered in these days. Additionally, a few days were removed from the data set due to hurricanes approaching Lee County and dramatically altering travel patterns.

Telephone Survey Description

A telephone survey was conducted to gain additional insight into the changes in variable pricing program participation over time. The survey targeted only those drivers who were eligible for the toll discount, traveled across the toll bridges, and resided in pre-selected zip codes relevant to the study. Guided by the objectives of this study, a survey questionnaire was designed to gather information on the socio-economic and commute characteristics of eligible drivers. The telephone survey was conducted in July 2001, approximately 3 years after the implementation of variable pricing program on toll bridges. A total of 4000 drivers were randomly selected from that group to be interviewed, and a total of 794 successful surveys were collected.

TRAFFIC VOLUME DATA ANALYSIS

To ascertain the impact of the variable pricing program on driver behavior, changes in traffic patterns of drivers who were *eligible* for the toll discount and those who were *ineligible* for the toll discount were examined. Earlier research on this project proved the variable tolls had a significant effect on traffic (shifting eligible peak period travelers to the discount periods) immediately following the introduction of the variable pricing program (*16,17,18*). To determine if the impact of the variable pricing program changed over time, the changes in travel patterns of eligible drivers over the period 1998 to 2002 will be compared to changes in travel patterns of ineligible drivers.

Similar trends in traffic volumes were observed on both the Cape Coral and the Midpoint Memorial Bridges except that on the Midpoint Memorial Bridge the traffic growth rate is much higher than on the Cape Coral Bridge. For brevity and clarity, the following sections focus only on the Cape Coral Bridge.

Traffic Flow Profile Estimation

Based on the minimum duration of the discount period, average half-hour daily traffic volumes (AHHDV) were calculated to analyze changes in traffic patterns over time. Figure 1 shows the impact of variable pricing on the distribution of daily traffic volumes between January to July 1998 and January to July 1999. The same overall trend was observed when comparing the traffic levels in subsequent years. For example, eligible traffic during the 6:30–7:00 a.m. discount period increased from 201 vehicles in 1998 to 517 vehicles in 2002. Comparing the traffic volumes between eligible and ineligible drivers for each half-hour (Figures 1 and 2), it is clear that the increase in eligible user traffic was much higher than ineligible traffic not only during toll discount periods but also during other time periods. However, this was not sufficient information to quantify the impacts of variable pricing program over time.

Changes in Traffic Patterns over Time

As overall eligible traffic on the bridges increased rapidly, determining the impact of variable pricing based on traffic volumes alone was not possible. The impact was examined by expressing traffic during each half-hour period as a percentage of average daily traffic. From these percentages, the change in each half-hour of traffic with respect to 1998 was calculated.

Figure 3 indicates the percentage change of eligible traffic between January to July 1998 and January to July 1999 on the Cape Coral Bridge. The bars in this figure illustrate that eligible drivers changed their time of travel to discount periods immediately after introducing variable pricing; therefore, toll discounts had an effect on traffic eligible for the toll discount (*6,16*). Figure 4 indicates how the variable pricing program impacted eligible drivers 3 years after the first year of implementation (January to July, 2002) with respect to base conditions (January to July, 1998). When comparing Figure 4 to Figure 3 it is clear that the time of travel of eligible drivers has changed over the years since variable pricing was implemented. It can be concluded that although the variable pricing was still influencing the time of travel of eligible drivers in 2002, this impact was reduced compared to 1999. This may indicate that drivers' use of variable pricing, and therefore the perceived value of toll discounts, has changed over time.

In the above discussion, changes in the percentage of eligible traffic during the respective periods cannot be directly attributed to the variable pricing program with any confidence. To confidently attribute these changes to the variable pricing program, changes in traffic patterns due to factors other than the variable pricing program must be controlled. This was attempted by considering the changes in time of travel of eligible traffic relative to ineligible traffic in the corresponding half-hour periods, as shown in the next section.

Toll Price Elasticities of Demand

Price Elasticities: Method 1

In this research, the elasticities of demand were calculated using a basic arc elasticity formula using initial price and demand as denominators. Using average prices and demands in the denominators greatly increase the elasticities calculated and were not used. In this method, changes in traffic volumes were calculated using the percentage change in each half-hour period. The changes in eligible and ineligible traffic for several years with respect to 1998 were calculated. Then, by subtracting the changes in the ineligible traffic from the eligible traffic, relative changes in the eligible traffic were determined. Equations 1 to 6 illustrate how the price elasticities of demand were estimated using this method.

$$PED_{(absolute)_i} = \frac{\left(\dfrac{P_{E_{i,j}} - P_{E_{i,R}}}{P_{E_{i,R}}}\right) \times 100}{\left(\dfrac{T_{vp} - T_{pre-vp}}{T_{pre-vp}}\right) \times 100} \tag{1}$$

$$Where\ P_{E_{i,j}} = \left(\frac{E_{i,j}}{E_j}\right) \times 100 \quad and \tag{2}$$

$$P_{E_{i,R}} = \left(\frac{E_{i,R}}{E_R}\right) \times 100 \tag{3}$$

Where,

$PED_{(absolute)_i}$ = price elasticity of demand calculated based on the absolute change in the eligible traffic for discount period *i*;

$P_{E_{i,j}}$ = percentage of average daily eligible trips during discount period *i*, in year *j*, for the January to July analysis period, where:

i = an index, in the range of 1 to 4, which identifies each discount period:

1 = 6:30–7:00 a.m. discount period,

2 = 9:00–11:00 a.m. discount period,

3 = 2:00–4:00 p.m. discount period, and

4 = 6:30–7:00 p.m. discount period;

j = an index in the range of 1999 to 2002, representing years examined;

$P_{E_{i,R}}$ = percentage of average daily eligible trips during discount period *i*, in year *R*, for January to July analysis period;

R = the reference year 1998;

$E_{i,j}$ = average daily eligible trips in discount period *i* for year *j*;

E_j = average daily eligible trips in year *j;*

$E_{i,R}$ = average eligible daily trips in discount period *i* during reference year *R* (1998);

E_R = total average daily eligible trips during reference year *R* (1998);

T_{vp} = toll with variable pricing discount ($0.50 or $0.25); and

T_{pre-vp} = toll prior to the implementation of variable pricing program ($1.00 or $0.50).

Next, the relative change in elasticity of eligible drivers with respect to ineligible drivers was found. This relative elasticity should help reduce the impact of external influences (such as gas price and the economy) on the results. To determine the relative changes in the price elasticity of demand, Equation 1 was modified as follows:

$$\left(PED_{relative}\right)_i = \frac{\left(\frac{P_{E_{i,j}} - P_{E_{i,R}}}{P_{E_{i,R}}}\right)\times 100 - \left(\frac{P_{IE_{i,j}} - P_{IE_{i,R}}}{P_{IE_{i,R}}}\right)\times 100}{\left(\frac{T_{vp} - T_{pre-vp}}{T_{pre-vp}}\right)\times 100} \tag{4}$$

Where $P_{E_{i,j}}$ and $P_{E_{i,R}}$ are as described in Equations 2 and 3and

$$P_{IE_{i,j}} = \left(\frac{IE_{i,j}}{IE_j}\right)\times 100 \tag{5}$$

$$P_{IE_{i,R}} = \left(\frac{IE_{i,R}}{IE_R}\right)\times 100 \tag{6}$$

Where,

$P_{IE_{i,j}}$ = percentage of average daily ineligible trips during discount period *i*, in year *j*, for the January to July analysis period;

$P_{IE_{i,R}}$ = percentage of average daily ineligible trips during discount period *i*, in year *R*, for January to July analysis period;

$IE_{i,j}$ = average daily ineligible trips in discount period *i* for year *j*;

IE_j = average ineligible daily trips in discount period *i* during reference year *R* (1998);

$IE_{i,R}$ = percentage of average daily ineligible trips during discount period *i*, in year *R*, for January to July analysis period; and

IE_R = total average daily eligible trips during reference year *R* (1998).

Price Elasticities: Method 2

In predicting the changes in long-run driver behavior due to variable tolls, a second method was considered, which may improve the prediction of variable pricing participation over the previous method. In this method, a more targeted approach was used and the time periods were divided into four time blocks, based on the discount periods. These time blocks included:

1. Early morning trips (6:30–7:00 a.m.), primarily commuter trips (results from a 1999 survey of bridge drivers). Due to the relatively inflexible nature of trip it was assumed to be unlikely that commuters changed their time of travel by more than 1 hour to obtain the toll discount; hence, 6:00–8:00 a.m. was included in one block.
2. The next block (8:00 a.m. to 12:00 noon) included the entire 9:00–11:00 a.m. discount period.
3. Similarly, the third block (12:00–5:30 p.m.) included the whole 2:00–4:00 p.m. discount period.
4. The evening discount period (6:30–7:00 p.m.) was separated in a block ranging from 5:30–7: 30 p.m.

Therefore, the equations used for this method were identical to those used in the previous method except E_j, E_R, IE_j, and IE_R consisted only of traffic in those four specific blocks of time.

Tables 1 and 2 show the results of the analysis for the Cape Coral and the Midpoint Memorial Bridges. All four elasticity estimates using different methods indicated that, in general, price elasticities of demand decreased over time. However, the percentage of reduction varies by method and time period.

As the traffic variations on both the bridges were similar, it could be reasonably expected that price demand elasticities might follow a similar trend. Also, if there was no trend, these estimates would be of little help in interpreting how drivers reacted to the variable toll over time. Results obtained by using relative changes in eligible traffic were, in general, slightly higher than the estimates using absolute changes in eligible traffic on the Cape Coral Bridge. Conversely, on the Midpoint Memorial Bridge estimates using absolute changes were much higher than those using relative changes during 6:30–7:00 a.m. discount period(compare Tables 1 and 2). This is partially due to the fact that on the Midpoint Memorial Bridge both eligible and ineligible trips increased rapidly. Only method 2 using the relative estimates gave similar results (either decreased or remained the same) for both the bridges. Also, the variation in elasticity estimates using method 2 is smaller than that for method 1. As this method also calculated elasticities based only on the time periods influenced by the respective discount periods, the results using method 2 were considered a better indicator of how price elasticities changed over time.

The results indicated that many drivers during the early morning period initially changed their time of travel to obtain a toll discount. However, over the course of time the impact of variable pricing has decreased, possibly indicating that many of these drivers switched back to their regular (peak period) time of travel. In 1999, 15.5 percent of drivers on the Cape Coral Bridge changed their time of travel to the 6:30–7:00 a.m. time period to obtain the toll discount. However, this was reduced to 3 percent during 2002. As many of these early morning trips were commute trips, it was possible that many drivers initially perceived the $0.25 discount to be sufficient to change travel behavior when considered over a large number of trips. However, some of these drivers may now feel that a savings of $0.25 per trip is not sufficient to warrant a change in their time of travel of commute trips. This was supported from the findings in the telephone survey that among eligible drivers who were surveyed, only 17.8 percent have the option of flexible working hours.

From the outset of the program, the variable toll had little to no impact on traffic patterns during the 6:30–7:00 p.m. time period. This was similar to the findings on SR 91 in California, that the workplace to home trips were more inelastic than home to workplace trips *(19)*.

The initial low elasticities found during the 9:00–11:00 a.m. and 2:00–4:00 p.m. time periods were not surprising, as many trips made during these time periods may by drivers who use the bridges infrequently. However, it was found that during these time periods elasticities were less likely to decrease than during other time periods. This may be due to the 2-hour duration of the discount period, which gives drivers more opportunity to shift their time of travel to these discount periods. Another reason could be some of the regular drivers in these time periods are retired, unemployed, or part-time employees and, hence, more price sensitive.

Peak Spreading Analysis

The phenomenon of diverting some peak period traffic to the shoulder of the peak as the level of congestion during the peak period increases is known as peak spreading. Hence, it may be possible to measure the effectiveness of the Lee County variable pricing program in diverting peak period trips to discount periods using the equations developed for peak spreading analyses. The results from this analysis were used to validate elasticity results estimated in the previous section.

Peak spreading models that were developed in the literature were based on traditional four-step travel demand modeling process (trip generation, trip distribution, mode choice, and transportation network assignment). The four-step travel demand modeling process does not consider the temporal distribution of travel demand, hence, the predicted growth rate in traffic volumes may not be accurate, especially in conditions of severe traffic congestion. Most of the peak spreading models were developed to address this issue. However, there were a few peak spreading models that were developed independent of the four-step modeling process. One such study conducted in the United Kingdom proposed a ratio to represent the degree of peak spreading occurring on a roadway *(20)*. This ratio was labeled the peak spreading road efficiency percentage (PSREP). PSREP was calculated by dividing typical peak period flow by a traffic volume that would occur if the maximum 15-minute volume during the peak period of a reference year (latest year) occurred during every 15-minute interval of the peak period in the reference year. Due to the differences in peak and off-peak period volumes and increase in eligible traffic over years using the highest 15-minute volume and using latest year as the reference year as in PSREP may overstate the impacts of a variable pricing program.

Considering the above factors and objectives of this study, a model (see Equation 7) was developed that represented how the traffic pattern may spread over the years during the time periods adjacent to the discount periods. Four time periods were considered for the analysis, based on the discount periods.

$$D_{k_{iN}} = \frac{\sum_{j=1}^{n} Q_{k_{ij_N}}}{n \times Q_{k_{i\,N}}} \tag{7}$$

where:

$D_{k_{iN}}$ = discount period volume spreading ratio in kth year for type of traffic N during the discount period i,

where;

k = number of years used for analysis, index from 1999 to 2002,

N = 1 if eligible traffic
2 if ineligible traffic, and

i = an index from 1 to 4:

1 = 6:30–7:00 a.m. discount period,

2 = 9:00–11:00 a.m. discount period,

3 = 2:00–4:00 p.m. discount period, and

4 = 6:30–7:00 p.m. discount period;

$Q_{k_{ij\,N}}$ = average half hourly daily traffic volume for type of traffic N in year k, during the jth half-hour period corresponding to the ith discount period, where;

j = an index from 1 to n representing the n half-hour periods corresponding to the ith discount period. For example, for 6:30 a.m. to 7:00 a.m., n = 4 (6:00 a.m. to 6:30 a.m., 6:30 a.m. to 7:00 a.m., 7:00 a.m. to 7:30 a.m., and 7:30 a.m. to 8:00 a.m.), and

$Q_{k_{iN}}$ = average half hourly daily traffic volume for type of traffic N in year k,

during the ith discount period.

Table 3 indicates the estimated discount period volume spreading ratios for the Cape Coral Bridge during the January to July analysis period. As mentioned earlier, these ratios would represent change in traffic during the time periods adjacent to the discount periods in the respective years. Thus, the volume spreading ratio relates the total flow during the most influencing periods for a particular discount period i to the flow during the discount period in the same year. An increase in this ratio indicates a smaller proportion of vehicles in the discount period.

From Table 15 it can be observed that initially in 1999 there was a maximum reduction (an average of 12 percent) in discount period volume spreading ratios than during any other analysis period. This would indicate that variable pricing had maximum impact during 1999. This result was quite similar to findings in the previous section. It could also be observed that the smallest changes occurred in these ratios during the 6:30 p.m. to 7:00 p.m. discount period over the years. This supports the earlier findings that variable pricing had least effect during this time period. Overall, this analysis supports the price elasticities of demand calculated in the earlier section that show a decrease in the impact of the variable tolls over time.

TELEPHONE SURVEY ANALYSIS

In the telephone survey the respondents were asked whether they had increased, decreased, or not changed their variable pricing participation over time. However, due to the small sample size respondents were classified into two groups instead of three: those who increased their variable pricing participation and those who had not. The characteristics of these two groups were compared and a descriptive statistical analysis was conducted to identify those demographic, socio-economic, and travel behavior attributes that were significantly different between these two groups. There were several socio-economic and commute characteristics that were significantly different ($p = 0.05$) between those respondents who were using variable pricing more often and those who were not using it more often (see Table 4). Drivers who made more frequent trips on the Cape Coral Bridge, were on commute trips, were a full-time employee, had more persons in their household, had a post-graduate degree, and were between 25–34 years old all were significantly more likely to have increased their variable pricing participation over time. Other characteristics like being retired or having a household income less than $16,000 indicated that drivers were less likely to increase their variable pricing participation. It was surprising to find that drivers with incomes less than $16,000 have not used the variable pricing more often. One possible explanation could be these low-income drivers had less flexibility in arriving at their workplace and hence, it was difficult for them to change their time of travel to discount periods.

CONCLUSIONS

This paper examined variable pricing program participation over time on the Lee County toll bridges, based on the traffic volume data and a revealed preference telephone survey. It was found that driver response to the variable toll has generally decreased over time.

When variable pricing was initially introduced in 1998, drivers responded positively by changing their time of travel to the discount periods (*16,17,18*). This change in time of travel was higher during the early morning discount period with the estimated relative elasticity of up to –0.42 on the Midpoint Memorial Bridge. However, driver participation dropped considerably by 2002 and elasticity estimates were only –0.11. It was also found that during evening time period fewer drivers were willing to change their time of travel to obtain the toll discount.

After the first year of implementation the price demand elasticities reduced during the 2:00–4:00 p.m. time period ranged from –0.10 to –0.07. Demand elasticity stabilized at this point. During the 9:00–11:00 a.m. discount period similar results were found. These results were also supported by developing a discount period volume spreading ratio that estimated the change in traffic during the time periods adjacent to the discount periods.

Using standard statistical tests, it was found that certain driver characteristics, such as drivers who made more frequent trips on the Cape Coral Bridge, were on commute trips, were a full-time employee, had more persons in their household, had a post-graduate degree, and were between 25–34 years old all were significantly more likely to have increased their variable pricing participation over time. Conversely, drivers who were retired or had a household income less than $ 16,000 were less likely to increase their variable pricing participation over time.

As opposed to the general results found in the reviewed literature, the results in this research showed that the long-run elasticity of variable pricing tolls was smaller in magnitude than the short-run elasticity. One reason that could explain this change is that approximately 94 percent of drivers obtained a toll discount of 25 cents and due to inflation the purchasing power of 25 cents has decreased over time. Factors such as alternative routes, different travel demographics, traffic congestion levels and size of toll discount may also influence the results obtained from other variable pricing projects.

Results in this research suggest that transportation planners and policy makers should consider how drivers' reaction to variable tolls might change over time and not considering this aspect may result in an over/under estimation of the expected benefits of a variable pricing program.

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LIST OF TABLES

LIST OF FIGURES

TABLE 1 Price Elasticities of Demand at the Cape Coral Bridge

Analysis	Year (*j*)	6:30–7:00 a.m.		9:00–11:00 a.m.		2:00–4:00 p.m.		6:30–7:00 p.m.	
		PED (a)	PED(r)	PED (a)	PED (r)	PED (a)	PED (r)	PED (a)	PED (r)
Method 1	1999	0.20	0.27	0.10	0.12	0.11	0.14	0.02	-0.01
	2000	0.10	0.09	0.10	0.14	0.09	0.10	0.02	-0.01
	2001	0.13	0.13	0.09	0.13	0.10	0.10	-0.01	-0.03
	2002	0.03	0.01	0.07	0.09	0.08	0.07	-0.06	-0.08
Method 2	1999	0.24	0.31	0.09	0.10	0.10	0.10	0.04	0.05
	2000	0.15	0.17	0.06	0.10	0.07	0.07	0.01	0.02
	2001	0.21	0.22	0.06	0.10	0.06	0.06	-0.02	0.01
	2002	0.08	0.06	0.04	0.06	0.05	0.06	-0.04	-0.03

PED (a) is price elasticities of demand estimated using absolute changes in eligible traffic.
PED (r) is price elasticities of demand estimated using relative changes in eligible traffic.
Price elasticities of demand are denoted by positive sign and negative price demand elasticities denote no effect of variable pricing.

TABLE 2 Price Elasticities of Demand at the Midpoint Memorial Bridge

Analysis	Year (*j*)	6:30–7:00 a.m.		9:00–11:00 a.m.		2:00–4:00 p.m.		6:30–7:00 p.m.	
		PED (a)	PED (r)	PED (a)	PED (r)	PED (a)	PED (r)	PED (a)	PED (r)
Method 1	1999	0.36	0.34	0.10	0.12	0.11	0.11	0.06	0.07
	2000	0.30	0.22	0.06	0.05	0.14	0.12	0.05	0.06
	2001	0.14	0.13	0.11	0.05	0.15	0.10	-0.02	-0.02
	2002	0.12	0.03	0.17	0.04	0.18	0.08	-0.03	0.00
Method 2	1999	0.43	0.42	0.09	0.10	0.10	0.09	0.11	0.11
	2000	0.39	0.28	0.07	0.05	0.14	0.09	0.07	0.06
	2001	0.21	0.14	0.10	0.06	0.13	0.06	0.07	0.06
	2002	0.31	0.11	0.14	0.06	0.14	0.05	0.08	0.03

PED (a) is price elasticities of demand estimated using absolute changes in eligible traffic.
PED(r) is price elasticities of demand estimated using relative changes in eligible traffic.
Price elasticities of demand are denoted by positive sign and negative price demand elasticities denotes no effect of variable pricing.

TABLE 3 Discount period volume spreading ratios for the Cape Coral Bridge (January to July)

Driver	Time Period	1998	1999	2000	2001	2002
ELIGIBLE	6:00–8:00 a.m.	1.11	0.99	1.03	1.00	1.07
	8:00–12:00 a.m.	1.15	1.10	1.11	1.11	1.13
	1:00–5:00 p.m.	1.03	0.99	1.00	1.01	1.01
	5:30–7:30 p.m.	1.15	1.13	1.15	1.16	1.18
INELIGIBLE	6:00–8:00 a.m.	1.10	1.14	1.11	1.10	1.09
	8:00–12:00 a.m.	1.08	1.08	1.10	1.10	1.09
	1:00–5:00 p.m.	1.02	1.02	1.02	1.02	1.02
	5:30–7:30 p.m.	1.14	1.15	1.15	1.16	1.15

TABLE 4 Socio-economic and Commute Characteristics of Lee County Toll Bridge Drivers

Characteristics	**Variable Pricing Program**	
	Increased (n=107)	**Did Not Increase (n=95)**
Q1: Number of trips per week		
On the Cape Coral Bridge*	5.55	3.81
On the Midpoint Memorial Bridge*	4.84	3.41
Q2: Years traveling on either of the bridges	9.99	10.60
Q4: Years having LeeWay Transponder and PrePay	3.22	3.12
Q15: Reason to consider variable pricing Discount		
1. Save money	64.50	57.90
2. Less traffic/Congestion	8.40	8.40
3. Contribute to better flow of traffic	7.50	4.20
4. Good for environment	0.90	1.10
5. Already drive during those hours	15.00	17.90
Q19: Primary trip purpose*		
1. Commuting	29.90	15.80
2. Delivering goods	0.00	1.10
3. Work-related	10.30	15.80
4. School	1.90	0.00
5. Shopping	28.00	35.80
6. Airport	1.90	1.10
7. Recreational	28.00	25.30
8. Drop Off/ Pick Up Person	0.00	1.10
Q20: Vehicle type		
1. Driving alone	59.80	53.70
2. 2-person Car or Vanpool	30.80	36.80
3. 3-person Car or Vanpool	8.40	7.40
4. Transit bus	0.00	0.00
5. Truck or Commercial vehicle	0.90	1.10
Q25: Employment status		
1. Full time*	46.70	31.60
2. Part time		9.50
3. Retired*	41.10	51.60
4. Not employed	7.50	5.30
5. Refused	0.00	2.10
Q26: Flextime		4.70
1. Availability: Yes	20.6	14.7
2. Availability: No	79.4	85.3
Q27: Flextime participation		
1. Yes	18.7	11.6

2. No	81.3	88.4
Q28: Reason for participating in Flextime program*		
1. Congestion, recreation, other	70.00	100.00
2. Variable Pricing toll discount	30.00	0.00
Q29: Number of people in the	2.57	2.27
Q30: Household type		
1. Single adult	10.40	18.10
2. Unrelated adults	5.70	5.30
3. Married without children	43.40	40.40
4. Married with children	33.00	31.90
5. Single parent family	4.70	3.20
6. Other	2.80	1.10
Q 31: Months living in Lee County	12.00	11.87
Q32: Education level		
1. Less than high school	1.00	3.20
2. High school graduate	25.70	26.90
3. Some college/Vocational	33.30	31.20
4. College graduate	25.70	30.10
5. Post-graduate degree*	14.30	8.60
Q33: Age		
1. 16–24 years	1.90	4.20
2. 25–34 years*	11.20	3.20
3. 35–44 years	14.00	13.70
4. 45–54 Years	19.60	17.90
5. 55–64 years	24.30	24.20
6. 65 years and older	29.00	36.80
Q 34: Gender		
1. Male	45.80	37.90
2. Female	54.20	62.10
Q 35: Household income		
1. Under $16,000*	1.20	8.60
2. $16,001 to $ 30,000	16.00	17.20
3. $30,001 to $ 50,000	22.20	25.90
4. $50,001 to $ 75,001	30.90	27.60
5: Over $ 75,000	29.60	20.70

* = Groups different at the 0.05 level.

Chi-Square tests were used to compare nominal data, Mann-Whitney tests were used to compare ordinal data, and t-tests are used to compare continuous data by group.

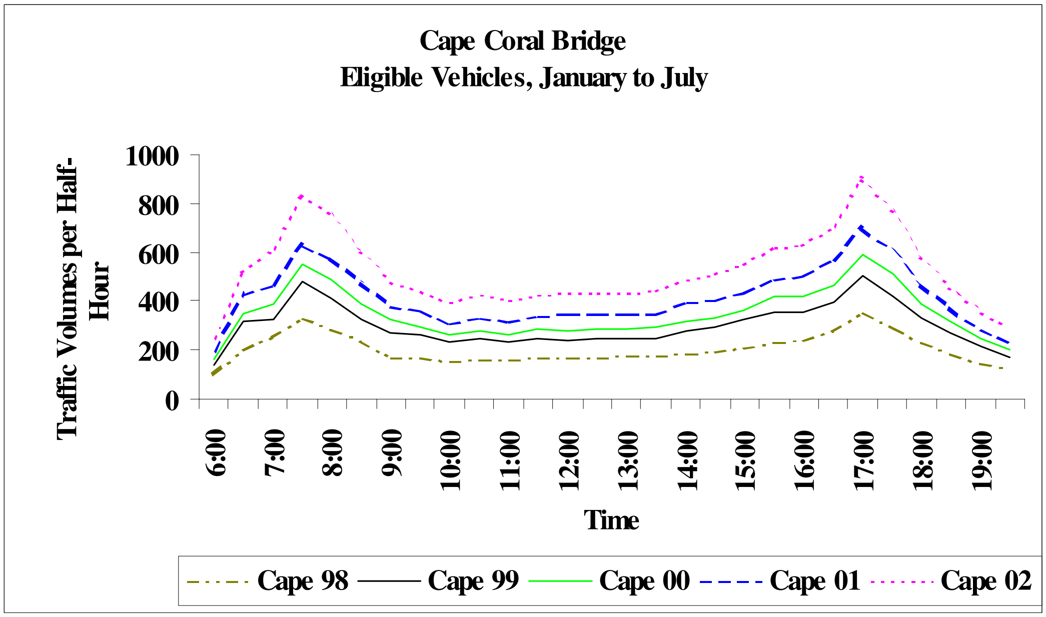

FIGURE 1 Comparison of Eligible User Traffic Profiles at the Cape Coral Bridge

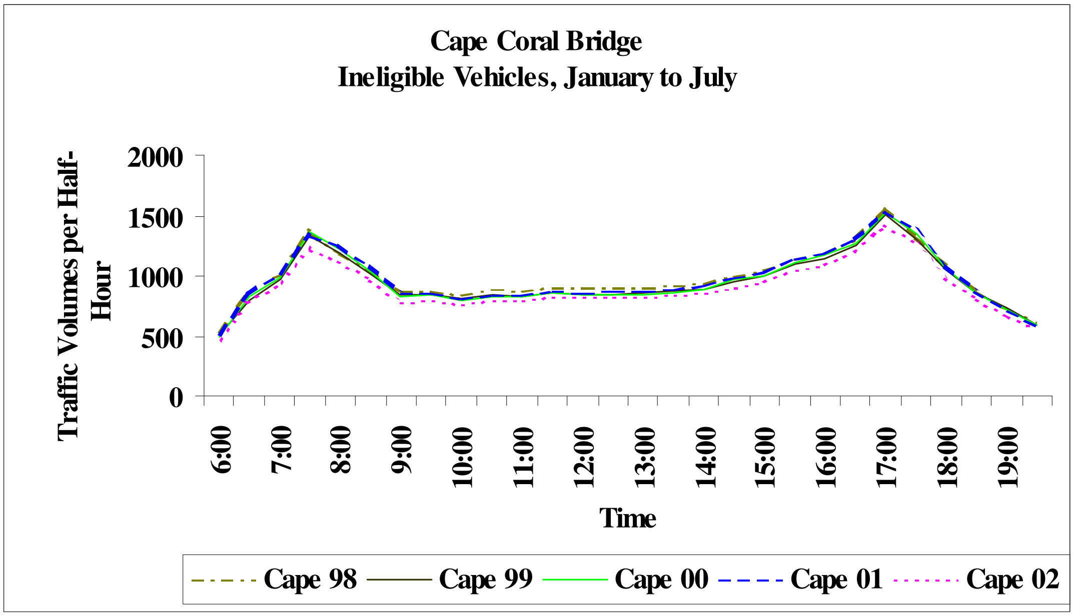

FIGURE 2 Comparison of Ineligible User Traffic Profiles at the Cape Coral Bridge

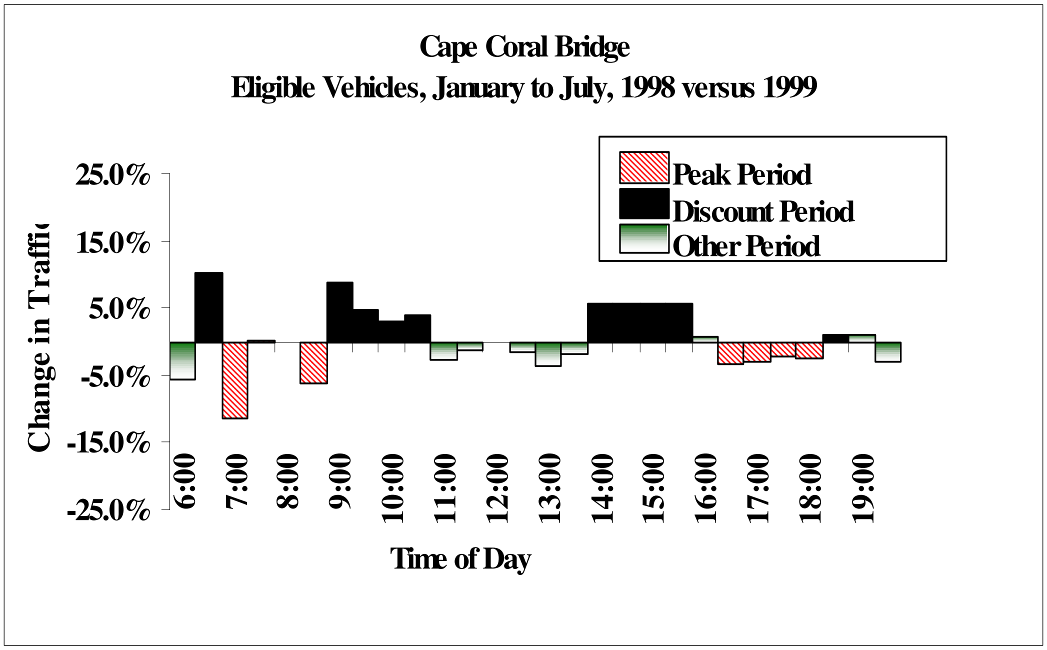

FIGURE 3 Percentage of Eligible Traffic Pattern Changes at the Cape Coral Bridge in 1999

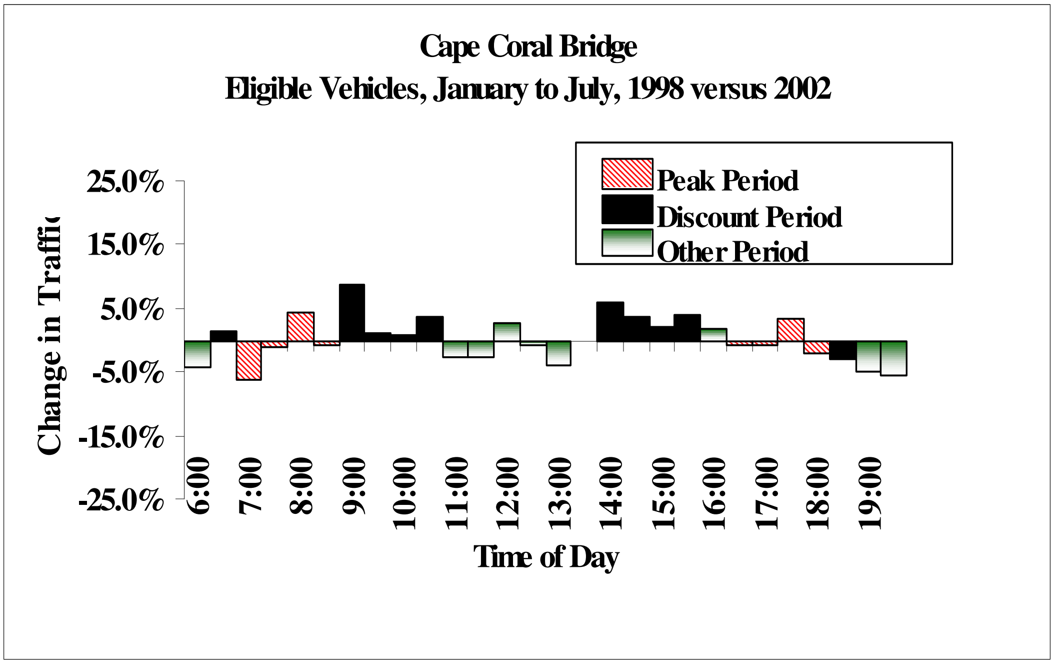

FIGURE 4 Percentage of Eligible Traffic Pattern Changes at the Cape Coral Bridge in 2002